Evaluation of manual dexterity in early education

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Abstract

Part of the recent research on fine motor skills questions the existence of a general factor of manual dexterity. If this manual dexterity factor is not proved this would affect the suitability of using motor development scales. The present study aimed at developing a set of tasks to evaluate manual dexterity in early education involving each hand to identify hand preference development. Specifically, the aim was to explore inter- and intra-task correlations by way of a series of object-manipulation tasks using objects of a size and weight adapted to children 3-6 years old, and to be administered easily by staff working in early education settings. In a first study using three tasks -*Posting coins*, *Moving pegs*, and *Threading eyebolts*- involving separately left and right hand (6 trials), 151 children aged 3-6 years have participated. The results show high inter- and intra-task correlations, and one factor explaining 64.03% of the total variance. Individual differences in motor skills and in hand preference are confirmed a year later, and correlate with children's writing skills when starting compulsory education. Implications for school and home are mentioned, emphasizing the interest of these type of studies for detecting typical/atypical developmental pathways.

Keywords: manual dexterity, early development, hand preference, fine motor skills, writing precursors.

Introduction

The study of motor development has traditionally focused more in changes taking place during the infancy years, and consequently, more in gross motor progressions (Adolph & Berger, 2006). Nevertheless, motor development continues improving in developing creatures. Not only new locomotor achievements are completed but relevant advances are shown as well in the more precise domain of hand use of tools. Recently, research literature on motor development has found moderate correlations between various tasks of hand dexterity pointing at the existence of a factor of manual dexterity in children: Bart, Hajami, & Bar-Haim, 2007; Ellinoudis, Evaggelinou, Kourtessis, Konstantinidou, Venetsanou, & Kambas, 2011; Kaiser, Albaret, & Doudin, 2009; Schulz, Henderson, Sugden, & Barnett, 2011; Van Waelvelde, De Weerdt, De Cock, & Smits-Engelsman, 2004; Wagner, Kastner, Petermann, & Bös, 2011. However, the lack of a significant correlation between the different tasks of manual dexterity included in motor development scales -e.g. Movement ABC-2- administered to children, has been highlighted against the existence of such a general factor, in favour of the specificity of the tasks (Haga, Pedersen & Sigmundsson, 2007). This lack of correlation could be due to the fact that some scales, e.g. the Movement ABC-2 do not specify which hand should do the task, or they demand the use of only one hand (generally the dominant one), making it difficult to determine whether there is a factor of manual dexterity (Henderson, Sugden, & Barnett, 2007). Following Lorås & Sigmundsson (2012), the present study uses three tasks with each hand to explore possible intra-task and inter-task correlations (3 tasks x 2 hands) in a sample of preschool children in Madrid, Spain. The interest of this study would be twofold. First, a theoretical interest, as this design could contribute to the debate of the existence of a manual dexterity factor vs. the tasks specificity. Second, an applied interest: compared with other countries, the Spanish educational system generally -not officially- demands an early introduction of children to the learning of reading and writing, so the identification of motor difficulties is relevant for the development of writing skills. The present study aims at designing a set of tasks to evaluate manual dexterity in early education involving both hands to identify hand preference development, and to investigate the possible existence of a manual dexterity factor common to various tasks (*ability*, as described by Fleishman & Bartlett, 1969), as opposed to task-specific skills in performing manual actions (Haga et al., 2007). Specifically, the aims are three: a) to compare the efficacy of each hand in performing three different tasks -*Posting coins, Moving pegs*, and *Threading eyebolts* (6 trials)-,

and calculate an index to study the development of manual preference in preschool children; b) to explore inter- and intra-task correlations using each hand in performing the three different tasks, and c) to identify possible difficulties in motor development in the participants.

Method

Participants

A total of 151 children (77 girls; 74 boys) aged 3-6 years participated. They attended the pre-school unit in a state-funded school in Madrid. Of them, 137 were right-handed, and 14 were left-handed, following the criterion of spontaneous use of either hand to draw or write her/his name. None of them had any sensory, motor or cognitive disability. The school assembly of educators approved the study, and every family received information of the study and signed the consent, for their children to participate in it.

Procedure and materials

A series of three object-manipulation tasks were designed with the following characteristics: reliable; using size and weight adapted to children 3-6 years old; attractive to children of the same age; short (less than 20 min.); cheap (with recycled material, and easy to make by hand); to be administered easily in small rooms, and by staff working in early education settings (not necessarily psychologists). The three tasks are described as follows:

Posting coins. Twenty coins (20 euro cent) should be inserted into a box with a slot, using a hand, while the other hand supports the box. Previous practice time with 5 coins was given. Time in seconds was measured since the first coin was touched until the last one was inserted.

Moving pegs. Using one hand, 15 wooden pegs (6 mm diameter, 30 mm long) had to be inserted in 15 holes separated each 2 cm upon a wooden board. After a previous practice with 5 pegs, time in seconds was measured since the first peg was touched until the last one was inserted.

Threading eyebolts. A string should be passed through 10 eyebolts (8 mm diameter) located on a board separated 4 cm each from left to right, repeating the action the other way. As it is a bimanual task, the hand inserting the string through the eyebolts changes from the first to the second time (left hand when starting from the left side; right hand when starting from the right side). Initial practice with 3 eyebolts was provided. Time in seconds was recorded since the string is moved towards the first eyebolt until it passes the last one.

The 3 tasks were performed twice: preferred hand (PH); non-preferred (NPH) hand, in the order each participant would prefer; and took place in the second session of a wider study on motor development, individually; during school time, in a separate room from the classroom.

Results

A preliminary analysis showed non-significant or no differences linked to gender and to right/left hand preference, so the data will be presented together. In all the tasks, better results were obtained with the preferred hand (PH) than with the non-preferred hand (NPH): *Posting coins*: PH vs. NPH Wilcoxon's z = -8.11, $p<0.001$; *Moving pegs*: PH vs. NPH Wilcoxon's z = -7.83, $p<0.001$; *Threading eyebolts*: PH vs. NPH Wilcoxon's z = -6.01, $p<0.001$. The ratio NPH/PH obtained values higher than 1 for the three tasks: 1.10, 1.13 and 1.12 corresponding to *Posting coins*, *Moving pegs* and *Threading eyebolts* (see Tab. 1).

Tab. 1. Performance using preferred hand and non-preferred hand in the three tasks.

	M	SD	Min.	Max.	Skewness	Kurtosis	NPH/PH
Posting PH	**37.41**	**6.54**	**26**	**60**	**.86**	**.72**	
Posting NPH	**41.18**	**7.78**	**26**	**72**	**.98**	**1.44**	1.10
Pegs PH	**45.59**	**9.15**	**27**	**76**	**.92**	**1.02**	
Pegs NPH	**51.29**	**10.58**	**34**	**90**	**1.11**	**1.44**	1.13
Threading PH	**23.73**	**6.55**	**14**	**53**	**1.41**	**2.95**	
Threading NPH	**26.69**	**7.78**	**16**	**65**	**1.81**	**5.44**	1.12

The inter- and intra-task correlations taking into account the six variables are shown in Tab. 2. All correlations were significant ($p < 0.001$), with values ≥ 0.4. In the three tasks the highest correlations were found between preferred hand and non-preferred hand (0.76, 0.72 y 0.66).

An exploratory factor analysis using the principal components method was performed for the six variables (Field, 2009). Kaiser-Meyer-Olkin test got a sample adequacy of 0.83, and Barlett's test of sphericity got a significance of $p < 0.001$. The principal components analysis (PCA) resulted in one factor explaining 64.03% of the total variance. Tab. 2 shows commonalities and saturations for each variable.

Tab. 2. Correlations, saturations and commonalities for the 6 tasks.

	Posting PH	Posting NPH	Pegs PH	Pegs NPH	Threading PH	Factor I	h^2
Posting PH						**.85**	**.72**
Posting NPH	**.76**					**.85**	**.72**
Pegs PH	**.65**	**.59**				**.81**	**.66**
Pegs NPH	**.59**	**.58**	**.72**			**.80**	**.64**
Threading PH	**.53**	**.51**	**.46**	**.43**		**.74**	**.55**
Threading NPH	**.48**	**.57**	**.44**	**.46**	**.66**	**.75**	**.56**
					eigenvalue	3.84	

A separate factor analysis for each hand (3 variables) resulted in a similar output: one factor explaining 69.91% for the preferred hand, and 69.69% for the non-preferred hand. Finally, average performance values for both hands in each task were calculated. Kaiser-Meyer-Olkin test of sample adequacy resulted in 0.69, while the level of significance in Barlett's sphericity test was: $p < 0.001$. The PCA showed one factor with an eigenvalue higher than 1 explaining 74.56% of the variance. Tab. 3 shows the correlations, commonalities and saturations for each task average value of both hands.

Tab. 3. Correlations, saturations and commonalities for each task.

	Mean BH	SD	Posting BH	Pegs BH	Threading BH	Factor I	h^2
Posting BH	**39.29**	**6.72**				**.89**	.80
Pegs BH	**48.45**	**9.14**	**.64**			**.84**	.70
Threading BH	**25.21**	**6.54**	**.62**	**.49**		**.82**	.68
					eigenvalue	2.24	

A follow up

In 2015, one year after conducting this study, children have been interviewed again with a double aim: to test the inter-rater reliability and to perform a test-retest comparison of the results obtained in 2014. The number of participants differed from Time 1: only the 3 and 4 year-old preschool groups in 2014, correspondingly the 4 and 5 year-old groups in 2015. Moreover, the relation between 5 year-olds hand dexterity in 2014, and writing speed in 2015 (1st year of Primary school) was studied.

Inter-rater reliability. The reliability of the measure –time in seconds- was analysed over a total of 357 trials (3 were discarded). Thirty children in the 4 and 5 year-old groups (former 3 and 4 year-olds) performed the tasks as used in the 2014 study. Time was recorded separately by the first author and an assistant. Four postgraduate students were trained, and each of them participated as assistant recording the time for seven or eight children's performance in the various tasks. As seen in Tab. 4, inter-rater and intra-class correlations were very high.

Tab. 4. Pearson and intra-class correlations for experimenter's and second rater's scores.

Second rater	Trials	Pearson's *r* *	Intra-class *
1	**96 (8 children)**	**0.998**	**0.998**
2	**84 (7 children)**	**0.998**	**0,998**
3	**83 (7 children)**	**0.996**	**0.996**
4	**94 (8 children)**	**0.996**	**0.996**

*** $p < 0.001$**

Test-retest reliability. Tasks were repeated 12 months later in 2015. A total of 98 preschool children participated, from 4 and 5 year-olds groups (former 3 and 4 year-olds). Data show a high correlation between the two scorings (2014 and 2015) on each task, highest for the *Posting coins* task with the preferred hand.

Tab. 5. Pearson correlations for each task in 2014 and 2015 performances.

Task	Pearson's *r*
Posting PH	**0.724**
Posting NPH	**0.650**
Pegs PH	**0.648**
Pegs NPH	**0.618**
Threading PH	**0.519**
Threading NPH	**0.459**

Hand dexterity data and writing speed relation. The relation between the results obtained from the 42 children in the last year of preschool education in 2014, and their writing speed one year later, when attending 1st year of primary school in 2015, was explored. Writing speed was evaluated by the number of letters produced per minute. A composite score (CS) of dexterity was calculated from the factor analysis conducted in 2014, and was correlated with writing speed, resulting in a Pearson r = -0.509. Due to the fact that the CS is higher in slower writers, the correlation of dexterity scores and writing speed is negative, a high scoring in dexterity pointing at a slower performance in writing.

The division of the group by the median of the composite score resulted in the data shown in Tab. 6: the 21 children with a better performance in hand dexterity tasks in 2014 (CS < 81), one year later could write almost ten letters more per minute than their peers having performed not so well the manual dexterity tasks.

Tab. 6. Relation of hand dexterity and writing speed one year later

Composite score	N	Speed**	s.d.
CS <81	**21 children**	**46.38 l/min.**	**10.83**
CS >81	**21 children**	**36.48 l/min.**	**10.11**

**** Mann-Withney *U* = 109.00 *z* = -2.808 *p* = 0.005.**

Conclusions

Results show an asymmetry favoring the preferred hand among participants. Ratio NPH/PH is similar to those found in adults (Annett, 1970; Bryden, Roy, McManus & Bulman-Fleming, 1997), and slightly lower than those in 4-11 yrs. old children (Hill & Khanem, 2009), thus suggesting that preschool children (3-to-5 years old) have already developed a clear hand asymmetry in the three tasks used in the study. The high inter-rater correlations guarantee the reliability of the evaluation procedure. The 2014-2015 comparison shows the stability of the hand difference. Moreover, differences in hand motor skills found in the 5 yrs. age-group in preschool are related to individual differences in writing speed identified in the same children one year later, when attending 1st year of Primary school.

These results contribute to the debate on the nature of manual skills pointing at commonalities across the various tasks and supporting the idea of a manual dexterity factor. The data suggest the convenience of early intervention among those children with lower scores on manual dexterity tasks, to prevent difficulties in their first steps in the learning of writing skills. The overt interest of children participating in the experiment could influence on the efficient performance of the tasks (Schulz, et al. 2011). Moreover, the strong emphasis of Spanish educational system on the preschool teaching of reading and writing, could influence positively on the data. Consequently the results of this study and other studies should be considered in relation to the specific educational context.

The next step in this research project is looking for the validity of the tests. The validation process includes three actions. First, administering several tasks involving the manipulation of cubes equipped with speed/acceleration sensors in order to identify individual differences in motor patterns and, eventually to detect

possible difficulties hard to be observed with the naked eye in some kids (Rivera, García-Herraiz, Alarcos, & Ortega, 2015). Second, developing a questionnaire to be filled in by early education staff and by families. Finally, administering the Movement ABC-2 (Henderson, Sugden, & Barnett, 2007) and PDMS-2 (Folio & Fewell, 2000) scales to evaluate motor development and compare children's performance with the results obtained in the present study.

A further aim with implications for schools and homes is to design new intelligent toys to detect semi-automatically typical/atypical development pathways.

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References

Adolph, K. E. & Berger, S. A. (2006). Motor development. In W. Damon & R. Lerner (Series Eds.) & D. Kuhn & R. S. Siegler (Vol. Eds.), *Handbook of child psychology: Vol 2: Cognition, perception, and language,* (6th ed., pp. 161-213). New York: Wiley.

Annett, M. (1970). The growth of manual preference and speed. *British Journal of Psychology*, *61*, 545-558.

Bart, O., Hajami, D., & Bar-Haim, Y. (2007). Predicting school adjustment from motor abilities in kindergarten. *Infant and Child Development*, *16*, 597-615.

Bryden, M. P., Roy, E. A., McManus, I. C., & Bulman-Fleming, M. B. (1997). On the genetics and measurement of human handedness. *Laterality*, *2*, 317-336.

Ellinoudis, T., Evaggelinou, C., Kourtessis, T., Konstantinidou, Z., Venetsanou, F., & Kambas, A. (2011). Reliability and validity of age band 1 of the Movement Assessment Battery for Children–2nd Edition. *Research in Developmental Disabilities*, *32*, 1046-1051.

Field, A. (2009). *Discovering Statistics using SPSS.* (3rd ed.). London: SAGE.

Fleishman, E. A., & Bartlett, C. J. (1969). Human abilities. *Annual Review of Psychology*, *20*, 349-380.

Folio, M.R., & Fewell, R.R. (2000). *Peabody Developmental Motor Scales -2*. Austin, TX: PRO-ED.

Haga, M., Pedersen, A. V., & Sigmundsson, H. (2008). Interrelationship among selected measures of motor skills. *Child: care, health and development*, *34*, 245-248.

Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2007) *Movement assessment battery for children-2nd edition [Movement ABC-2]*. London: The Psychological Corporation.

Hill, E. L., & Khanem, F. (2009). The development of hand preference in children: The effect of task demands and links with manual dexterity. *Brain and Cognition*, *71*, 99-107.

Kaiser, M. L., Albaret, J. M., & Doudin, P. A. (2009) Relationship between visual-motor integration, eye-hand coordination, and quality of handwriting. *Journal of Occupational Therapy, Schools, & Early Intervention*, *2*, 87-95.

Lorås, H., & Sigmundsson, H. (2012). Interrelations between three fine motor skills in young adults. *Perceptual and Motor Skills*, *115*, 171-178.

Rivera, D., García-Herraiz, A., Alarcos, B., Velasco, J. R., & Ortega, J. E. (2015) Smart toys designed for detecting developmental delays. Submitted.

Schulz, J., Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2011). Structural validity of the Movement ABC-2 test: Factor structure comparisons across three age groups. *Research in Developmental Disabilities*, *32*, 1361-1369.

Van Waelvelde, H., De Weerdt, W., De Cock, P., & Smits-Engelsman, B. C. M. (2004). Aspects of the validity of the Movement Assessment Battery for Children. *Human Movement Science*, *23*, 49-60.

Wagner, M. O., Kastner, J., Petermann, F., & Bös, K. (2011) Factorial validity of the Movement Assessment Battery for Children-2 (age band 2). *Research in Developmental Disabilities*, *32*, 674-680.